Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Various agencies have contributed information to this review of past and current myrtle rust research and the Challenge would like to acknowledge the willingness agencies have shown to engage in Ngā Rākau Taketake (NRT) by sharing their research data to help us better understand the research landscape. Accessing and pulling data such as this together is a complicated task and we are fully aware that that this list may not be complete.

The projects in this document are grouped by the Myrtle Rust Strategic Science Advisory Group (SSAG) Themes and ordered alphabetically within.

WE NEED YOUR HELP: This is a living document and we need your help to find those additional publications, research projects or programmes that we may not be aware of. If you have information on Myrtle Rust research that has been undertaken within the New Zealand science system, Masters, PhD's, internally funded projects, larger MBIE programmes etc., we would appreciate you letting us know via email to NRTsupport@bioheritage.nz

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Aotearoa myrtle rust surveillance library	This report describes the following components of the surveillance library: - Myrtle rust surveillance data compiled from multiple data sources - Iconic trees layer of important myrtaceous plant hosts - Infection risk and latent period rasters created using the Myrtle Rust Process Model/climatic risk mode	Ministry for the Environment	Plant and Food Research	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2020	Campbell R, Teasdale S, Bradshaw P. 2020. Aotearoa myrtle rust surveillance library. *A Plant & Food Research report prepared for: Ministry for the Environment.* September 2020. Milestone No. NA. Contract No. NA. Job code: P/346029/01. PFR SPTS No. 19875.
Assessing long range dispersal spread of myrtle rust to New Zealand mainland	The principal focus of this work was to assess the risk of aerial spread of myrtle rust spores from each of Australia, Raoul Island, and New Caledonia to the main islands of New Zealand, in areas not yet affected by the disease, and from known infected areas to other not yet infected places. The work provided information on the risk and change of risk of aerial spread, if any, as the result of myrtle rust detection in Raoul Island. The derived information will be crucial, if aerial transmission risk has increased.	Ministry for Primary Industries	National Institute of Water and Atmospheric Research	Complete	Theme A - Surveillance, monitoring and impact of disease	Risk Assessment/ Ecosystem Impacts	Unknown	The initial contract was completed and further work funded. Outcomes used internally in management.

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Assessing the risk of long-range aerial dispersal of Myrtle Rust to New Zealand and Raoul Island	Due to the potential aerial spread of the Myrtle rust spores, NIWA has conducted comprehensive modelling assessment of long-range aerial transport opportunities for spores to be blown to New Zealand from sources in the East Coast of Australia and New Caledonia, where Myrtle Rust is established, as well as from Raoul Island where it was detected in early 2017. The assessment was carried out for the period July 1, 2016 to June 30, 2017. NIWA was also requested to monitor possible ongoing airborne transport to New Zealand from external sources after June 30, 2017 and to also model possible aerial transport from infected sites within New Zealand. The output provided to MPI is intended to provide guidance for surveillance efforts by identifying areas of potentially greater exposure to Myrtle Rust spores.	Ministry for Primary Industries	National Institute of Water and Atmospheric Research	Complete	Theme A - Surveillance, monitoring and impact of disease	Risk Assessment/ Ecosystem Impacts	2017	Turner R, Moore S, Paul V. 2017. Assessing the risk of long-range aerial dispersal of Myrtle Rust to New Zealand and Raoul Island. *NIWA CLIENT REPORT No: 2017152WN Report*
Biosecurity network interventions	Research focused on network analyses of pathways, routes of spread of pests and pathogens, and 'nodes' or hotspots that may be hubs for spread throughout NZ. PhD research is exploring the potential to develop a Myrtle Rust Incursion Model using MPI data. Data collected from 13 nurseries and 70 public land spaces in mainland New Zealand following the 2017 incursion of myrtle rust will be used to network the spread of myrtle rust through New Zealand and identify whether human mediated dispersal played a role in pathogen spread during early stages of the incursion.	BioHeritage National Science Challenge	Bio-Protection Research Centre	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2022	Analyses of these data have not indicated a link between human mediated dispersal and the initial outbreak. Researchers associated with the Australian Department for Primary Industries have expressed interest in supplying information on the Australian response to the myrtle rust pathogen introduction which would allow for an international comparison study of outbreak responses. Marshall M, Sutherland R, Hulme PE. 2021. Assessing the role of plant trade networks in the vulnerability of forest nurseries to plant pathogens. *Australasian Plant Pathology* **50**(6): 671-681.
Chasing myrtle rust in New Zealand: host range and distribution over the first year after invasion	After the detection of the myrtle rust pathogen, *Austropuccinia psidii*, in New Zealand, a biosecurity response was initiated, including a wide-spread surveillance programme. Through an intensive public awareness initiative, the general public was highly engaged in reporting myrtle rust infections and added significant value to the surveys by reporting first detections from most of the areas that are now known to be infected. During the first year of the response, *Austropuccinia psidii* was found in areas that were predicted to be at high infection risk in previous modelling studies. Significant surveillance resources were deployed to different parts of the country and the response surveillance team contributed to most of the new host species finds.	Ministry of Primary Industries	Ministry of Primary Industries	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2020	Toome-Heller, M., Ho, W.W.H., Ganley, R.J. *et al.* 2020. Chasing myrtle rust in New Zealand: host range and distribution over the first year after invasion. *Australasian Plant Pathol.* **49**: 221–230

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Control, Protect, Cure: Tools for Detection and Management	Incorporating research from many areas (i.e. microbiology, nanotechnology, chemistry, social science) to advance science and knowledge into new tools for the detection and management of the plant pathogens: kauri dieback (KD) and myrtle rust (MR). This mahi specifically considers that the tools are for use by kaitiaki and land managers. Research Area 1: Detection Tools • RA1A Remote detection of *Phytophthora agathidicida* (KD tool) • RA1B Development and deployment of an *Austropuccinia psidii* biotype differential diagnostic test (MR Tool) Research Area 2: Disinfection (MR tool) Research Area 3: Mātauranga bioactives • RA3A Mātauranga Bioactives (KD Tool) • RA3B Mātauranga based digital monitoring platform - Cultural indicator app (KD & MR Tool) Research Area 4: Te Whakahononga • An innovative Māori engagement programme reflecting a waka hourua approach	BioHeritage National Science Challenge - Ngā Rākau Taketake	Scion	Current	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance Control Protect, Cure Mobilising for Action	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Theme 5: Control, Protect, Cure
Developing surveillance and monitoring tools	The project developed a framework for long-term surveillance and monitoring of myrtle rust in New Zealand: i. ground-based tools to assist with the long-term surveillance and monitoring of myrtle rust in New Zealand; ii. these ground-based tools were used to monitor the incidence and progression of myrtle rust on native species under natural conditions; iii. the potential of remote sensing technologies to provide alternative methods to monitor difficult to access material or extensive forest areas were investigated	Ministry for Primary Industries	Scion	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2019	Ganley B, Beresford R. 2019. Improved myrtle rust surveillance: Selection of indicator species for surveillance (3.1-5) *Biosecurity New Zealand Technical Paper No: 2019/20* Ganley B, Soewarto J, Sutherland R, Froud K, Marsh A, Leonardo EM, Pearse G. 2019. Improved myrtle rust surveillance (3.1- 2 & 3.1 -3). *Biosecurity New Zealand Technical Paper No.: 2019/21* Sutherland R, Soewarto J, Beresford RM, Ganley B 2020. Monitoring *Austropuccinia psidii* (myrtle rust) on New Zealand Myrtaceae in native forest. *New Zealand Journal of Ecology* **44**(2): 5 Pearse GD, Watt MS, Soewarto J; Tan AYS. 2021. Deep Learning and Phenology Enhance Large-Scale Tree Species Classification in Aerial Imagery during a Biosecurity Response. *Remote Sens.* **13**, 1789.
Development of a Lucid key	This project aims to rapidly identify *Myrtaceae* plants even by a lay person who comes across suspected Myrtle rust symptoms, so that reporting, control and long-term management of the devastating disease is enabled.	Ministry for Primary Industries	Manaaki Whenua	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2020	The NZ Myrtaceae Key is a free and easy-to-use app that makes it simple to identify plants in the myrtle family that grow in Aotearoa New Zealand. It includes more than 100 of the most commonly found species, subspecies, hybrids and cultivars, in New Zealand. Newsletter Story: Need help to identify a myrtle? There's an app for that Web based tool: NZ Myrtaceae Key

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
General/citizen-led surveillance framework for biosecurity incursions	Research focus on building apps for public use to detect biosecurity incursions, and analysis of data formerly called 'passive surveillance' data to strengthen the biosecurity system. The pilot trial of the app was 'Myrtle Rust Reporter', and this part is complete.	BioHeritage National Science Challenge	Scion	Complete	Theme A - Surveillance, monitoring and impact of disease	Mobilising for Action Integrated Surveillance	2019	The Myrtle Rust Reporter part of this project is complete. The app is publicly available from Playstore (uploaded by 500+ customer) and iStore. Linked to the iNaturalist site where myrtle rust observational information from app users can found in relation to location, host species, identifier and observer. Grant A, Pawson SM, Marzano, M. 2019. Emerging stakeholder relations in participatory ICT design: renegotiating the boundaries of sociotechnical innovation in forest biosecurity surveillance. Forests, **10**, 836; 1-24 Pawson SM, Sullivan JJ, Grant A 2020. Expanding general surveillance of invasive species by integrating citizens as both observers and identifiers. *Journal of Pest Science* **93**(4): 1155-1166.
Generic rust pathways	The long-distance dispersal of many plant pathogens has been well documented. This phenomenon is also common in Australasia, with wind currents and movement of people and possibly plant material facilitating introduction of several rust pathogens from Australia to New Zealand. The history of the arrival, survival and spread of three rust pathogens from Australia to New Zealand is outlined. This information is used to assess the risks posed to New Zealand by other rust pathogens that occur in Australia and to assess ways to minimise these risks.	New Zealand Foundation for Research, Science and Technology	Plant and Food Research	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2002	Viljanen-Rollinson SLH, Cromey MG 2002. Pathways of entry and spread of rust pathogens: Implications for New Zealand's biosecurity. *New Zealand Plant Protection* **55**: 42-48.
Generic rust pathways	Modelling dispersal across the Tasman Sea using historic data	New Zealand's Foundation for Research, Science and Technology	Plant and Food Research	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2008	Kim KS, Beresford RM 2008. Use of a spectrum model and satellite cloud data in the simulation of wheat stripe rust (*Puccinia striiformis*) dispersal across the Tasman Sea in 1980. *Agricultural and Forest Meteorology* **148**: 1374–1382.
Integrated Surveillance: Building a Mātauranga Māori based surveillance framework for plant pathogens	To date, there are few initiatives that integrate indigenous knowledge and approaches into the surveillance system for plant pathogens in Aotearoa New Zealand. This project aims to develop a Mātauranga Māori Framework for Surveillance (MMSF) for plant pathogens to enable better engagement of Hapū/Iwi across central and local government agencies, including the Ministry for Primary Industry (MPI), Department of Conservation (DOC), regional councils, stakeholders and communities engaged in a surveillance effort.	Ngā Rākau Taketake (BioHeritage National Science Challenge)	Manaaki Whenua Landcare Research	Current	Theme A - Surveillance, monitoring and impact of disease Theme C - Te Ao Māori and Mātauranga Māori	Oranga Integrated Surveillance	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Theme 4: Integrated Surveillance Sharma P, Martin M, Swanlund D. 2023. MapSafe: A complete tool for achieving geospatial data sovereignty. Transactions in GIS.

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
	Research Area 1: MMFS Research Area 2: Integrated Intelligence Platform Research Area 3: Proof of Absence Model							
Mapping myrtle species distribution	Project 1: Development of national-scale species distribution models (SDMs) for all native Myrtaceae species based on occurrence records from vegetation plot records, DOC's Bioweb database, national herbaria and citizen science databases. Project 2: Developing improved remote sensing methods for mapping *Metrosideros* species in New Zealand. Using mix of remote sensing technologies and novel machine learning methods.	Ministry for Primary Industries	Scion	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2019	Pearse G, Soewarto J, Watt M, Estarija H. 2019. Developing improved methods for mapping *Metrosideros* species in New Zealand. *Biosecurity New Zealand Technical Paper No.*: 2019/23 McCarthy JK, Richardson SJ, Cooper JA, Bellingham PJ, Wiser SK. 2019. Species distribution models of the native New Zealand Myrtaceae. *Biosecurity New Zealand Technical Paper No.*: 2019/22 McCarthy JK, Wiser SK, Bellingham PJ, Beresford RM, Campbell RE, Turner R, Richardson SJ 2021. Using spatial models to identify refugia and guide restoration in response to an invasive plant pathogen. *Journal of Applied Ecology* **58**(1): 192-201
Mapping of native Myrtaceae species in New Zealand	To enhance and improve 'polygonised' species maps previously created for 19 native Myrtaceae taxa.	Department of Conservation	Manaaki Whenua	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2017	Wiser, SK, Cooper JA, Arnst EA and Richardson SJ. 2017. Mapping of native Myrtaceae species in New Zealand. *Contract Report LC3065* (MWLR)
Molecular diagnostics	Development of a molecular method to quickly and accurately identify myrtle rust.	Ministry for Primary Industries	Ministry for Primary Industries	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2016	Baskarathevan J, Taylor RK, Ho W, McDougal RL, Shivas RG, Alexander BJR. 2016. Real-time PCR Assays for the detection of *Puccinia psidii*. *Plant Disease* **100**(3): 617-624.
Myrtaceae DNA barcoding reference library	In 2014 MPI funded Scion to develop a molecular barcoding database to allow reliable and rapid identification of Myrtaceae plants to the species, as part of their preparedness plan. The barcoding database can determine all New Zealand Myrtaceae present to genus and over 100 to species level.	Ministry for Primary Industries	Scion	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2016	Buys MH, Flint HJ, Miller EM, Yao H, Caird AR and Ganley RJ. 2016. Preparing for the invasion: Efficacy of DNA barcoding to discern the host range of myrtle rust (*Puccinia psidii*) among species of Myrtaceae. Forestry: *An International Journal of Forest Research*, **89**(3): 263–270
Myrtaceae DNA barcoding reference library	*Leptospermum scoparium* is morphologically a highly variable species found in mainland Australia, Tasmania and New Zealand. In New Zealand up to six morphologically distinct varieties of this species have been described, although only two (*var. scoparium and var. incanum*) are now formally recognized. In the present study we provide a first examination of genetic diversity in this culturally and commercially important species with the aim of gaining insights into its origins and evolution. Evolutionary and taxonomic implications are discussed.	Ministry for Primary industries / Ministry for Business, Innovation and Employment (MBIE)	Scion	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2018	Buys MH, Winkworth R, Lange PJ, Wilson P, Mitchell N, Lemmon A, Lemmon E, Holland S, Cherry J, Kláptště J. 2019. The phylogenomics of diversification on an island: applying anchored hybrid enrichment to New Zealand *Leptospermum scoparium* (Myrtaceae). *Botanical Journal of the Linnean Society*. **191**(1): 1-17

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Myrtle rust detection kit	Development of an innovative molecular technique to use in an inexpensive and easy kit that can be deployed in the field, that will successfully diagnose all biotypes of *Puccinia psidii* and the asexual Uredoforms while not cross-reacting with any rust fungi present in NZ and other *Puccinia* species. This approach will build on the success model of a Generic LFD test kit for *Phytophthora*, extending to make use of DNA isothermal amplification without the need for an expensive device.	Ministry for Business, Innovation and Employment - Strategic Science Investment Fund (MBIE – SSIF)	Massey University	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2019	A LAMP test has been developed and validated in the laboratory. Testing of field collected samples indicates detection of asymptomatic plant material and of spores swabbed from hard surfaces. e.g. leaves of non-host species or footpaths.
Myrtle Rust Sentinel Project	This paper outlines the learnings to date from the myrtle rust sentinel survey that has run at Auckland Botanic Gardens since 2014, initially with the aim of detecting the arrival of myrtle rust in NZ and subsequent to its arrival detecting preferred hosts and documenting impacts.	Auckland Council	Auckland Botanic Gardens	Complete	Theme A - Surveillance, monitoring and impact of disease Theme B – Epidemiology, ecosystem and resilience	Integrated Surveillance Risk Assessment and Ecosystem Impact	N/A	Bodley E, Stanley R 2021. Myrtle Rust Sentinel Project at Auckland Botanic Gardens, New Zealand. Australasian Plant Conservation **30**(2): 19-22.
Impacts of myrtle rust in New Zealand since its arrival in 2017	This paper reviews the impacts of myrtle rust in New Zealand since its arrival in 2017 including, surveillance, climatic suitability, and susceptible native Myrtaceae.	N/A	Plant and Food Research	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance Host, Pathogen and Environment	2019	Beresford R, Smith G, Ganley B, Campbell R. 2019. Impacts of myrtle rust in New Zealand since its arrival in 2017. New Zealand Garden Journal 22(2): 5-10.
Rapid Field Detection of the Highly Invasive Myrtle Rust Pathogen	Fungus *Puccinia psidii* has been deemed a high priority for MPI readiness and response. The LFD would be a plant health diagnostic tool which could be purchased for the following purposes: In-field use to determine the presence of absence of myrtle rust thereby allowing a quick response to limit its spread into nature reserves, state forests and urban areas etc., An easy to use tool for both passive and targeted surveillance. This would be the first time an LFD has been developed for myrtle rust	Ministry for Primary Industries	Food and Environment Research Agency (United Kingdom)	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2018	Work commenced but at an early milestone stage it was not looking promising so it was discontinued. "While the LFD has been deployed during the outbreak in New Zealand, the project team has agreed to discontinue further development work due to the limited long-term use of the LFD by MPI. Limitations identified are that it cannot always detect if infection levels are low or when they are pre-symptomatic. The LFD did not detect some of the samples with small amount of rust pustules."

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Sentinel plants to forecast & future proof NZ plant systems against pests & diseases	Biosecurity outcome: The effectiveness of the sentinel plant concept is well understood and demonstrated with reference to its use as a predictive border biosecurity tool in productive and natural ecosystems. This project will establish the scientific validity for sentinel plants as a border biosecurity tool in productive and natural systems		Better Border Biosecurity (B3)	Complete	Theme A - Surveillance, monitoring and impact of disease	Integrated Surveillance	2020	Boyd-Wilson KSH, Marroni MV, McNeill MR, Teulon DAJ. 2021. New Zealand indigenous Myrtaceae in foreign botanic gardens: testing the sentinel plant concept for biosecurity risk assessment. *New Zealand Plant Protection* **74**(1): 1-9
Te Whakahononga	Te Whakahononga provides Māori-centred research, kaupapa Māori and research involving Māori, and applies Mātauranga Māori-derived solutions to enhance resilience of forest ecosystems subject to kauri dieback and myrtle rust; as well as authentic empowerment of mana whenua and their communities to increase protection for our ngahere and for future generations. Te Whakahononga integrates mātauranga Māori and western scientists across 15 nominated geographically spread Biodiversity Management Areas ('BMAs') and with discreet mātauranga Māori-centred research projects mana whenua are invited and engaged to develop mātauranga Māori research. Learnings from this new approach are being documented by social scientists to enable wider future applications.	Ngā Rākau Taketake (BioHeritage National Science Challenge)	Manaaki Whenua Landcare Research	Current	Theme A - Surveillance, monitoring and impact of disease Theme C - Te Ao Māori and Mātauranga Māori	Aligns with all seven NRT themes	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Te Whakahononga
A new species of *Mycodiplosis* gall midge (Diptera: Cecidomyiidae) feeding on myrtle rust *Austropuccinia psidii*	Morphological description of the male, female, pupa and larva, COI sequence and currently known geographical distribution of *Mycodiplosis constricta* sp. *nov*. in New Zealand.	Ministry for Business, Innovation and Employment (MBIE)	Scion	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2022	Kolesik P, Sutherland R, Gillard K, Gresham B, Withers TM 2021. A new species of *Mycodiplosis* gall midge (Diptera: Cecidomyiidae) feeding on myrtle rust *Austropuccinia psidii*. *New Zealand Entomologist* **44**(2): 121-129.
A. psidii de novo genome sequencing	How *A. psidii* causes disease is unknown. Sequencing and analysing pathogen genomes has revealed potential mechanisms of pathogenicity that can be targeted by breeding or other responses. The only publicly available *A. psidii* sequence data is of low quality and is not suitable for analysis.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2019	Chagné D, Deng C, Wu C, Templeton M, Smith G. 2019. MPI 18608 Project Report Topic 2.1 — *Austropuccinia psidii* de novo sequencing. *Biosecurity New Zealand Technical Paper* No: 2019/39. Tobias PA, Schwessinger B, Deng CH, Wu C, Dong C, Sperschneider J, Jones A, Lou Z, Zhang P, Sandhu K and others 2020. *Austropuccinia psidii*, causing myrtle rust, has a gigabase-sized genome shaped by transposable elements. *G3 Genes|Genomes|Genetics* **11**(3): 16.

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Assessing climatic risk of myrtle rust in NZ	Updating climate matching models for myrtle rust and provide forecast and hind-cast simulations of changing risk profiles across NZ based on recent climate data and climate forecasts. This will help answer questions like "how will risks change as we head into winter?" or "where should we look for the disease in September?"	Ministry for Primary Industries	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Risk Assessment/ Ecosystem Impacts	2018	Beresford RM, Turner R, Tait A, Paul V, Macara G, Yu ZD, Lima L & Martin R. 2018. Predicting the climatic risk of myrtle rust during its first year in New Zealand. *NZ Plant Protection* 71, 332-347
Assessment of the risk of introduction of other Myrtle Rust biotypes to NZ	The pandemic biotype of *Austropuccinia psidii* is the variant of this pathogen present in New Zealand. Two other biotypes, with different reactions on hosts, have been described overseas. It is important to understand the potential impact of these other biotypes should they arrive in this country by pro-actively screening New Zealand *Myrtaceae* for susceptibility.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Risk Assessment/ Ecosystem Impacts	2019	Soewarto J, Sutherland R, Ganley B, du Plessis E, Barnes I, Wingfield M, Granados G. 2019. Topic 1.3 — Assessment of other myrtle rust biotypes. Biosecurity New Zealand Technical Paper No: 2019/35 Soewarto J, Hamelin C, Bocs S, Mournet P, Vignes H, Berger A, Armero A, Martin G, Dereeper A, Gautier S, Carriconde S, Maggia L. 2019. Transcriptome data from three endemic *Myrtaceae* species from New Caledonia displaying contrasting responses to myrtle rust (*Austropuccinia psidii*). *Data in Brief* (22) 794-811 (Funded by GLENCORE, IAC and CIRAD)
Austropuccinia psidii (myrtle rust) infection rates on *Lophomyrtus* spp. fruits in New Zealand.	The objective of this study was to look at how the pathogen affects the development of *Lophomyrtus* spp. fruits and the effects on seed viability. Phase 2 undertaken by Ngā Rākau Taketake: Theme 3 Rick Assessment and Ecosystem Impacts.	Phase 1: Department of Conservation Phase 2: BioHeritage National Science Challenge - Ngā Rākau Taketake	Scion	Current	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	N/A	To be completed and publication due in 2023. Related Research: Beresford R, Stanley R, Bodley E. 2020. Field susceptibility of horticultural selections of *Lophomyrtus* species and hybrids to myrtle rust (*Austropuccinia psidii*). 7 p. Plant and Food Research funded internal report: PFR SPTS no. 19707. **NOTE:** This report is held by Plant and Food Research – please contact them regarding availability
Beyond Myrtle Rust: next generation tools to 'engineer' forest ecosystem resilience to plant pathogens Research Area 1.1: Pathogen dynamics	This programme aims to accelerate understanding of pathogen dynamics, improve predictions of complex pathogen impacts on ecosystem function, develop novel, socially acceptable mitigation technologies and enhance kaitiakitanga within myrtle rust affected landscapes. • Monitoring of *A. psidii* population genetics and associated host symptoms. • Sexual reproduction drives pathogen diversity and may widen host range - focus on understanding host/environmental drivers of sexual reproduction • Both natural and planted Myrtaceae stands studied	Ministry for Business, Innovation and Employment (MBIE)	Manaaki Whenua	Current	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	N/A	To be completed in 2024. For additional updates and information go to the Beyond Myrtle Rust website. Ferrarezi JA, McTaggart AR, Tobias PA, Hayashibara CAA, Degnan RM, Shuey LS, Franceschini LM, Lopes MS, Quecine MC 2022. *Austropuccinia psidii* uses tetrapolar mating and produces meiotic spores in older infections on *Eucalyptus grandis*. *Fungal Genetics and Biology* 160: 103692. Soewarto J, Somchit C, du Plessis E, Barnes I, Granados GM, Wingfield MJ, Shuey L, Bartlett M, Fraser S, Scott P and others 2021. Susceptibility of native New Zealand Myrtaceae to the South African strain of *Austropuccinia psidii*: A biosecurity threat. Plant Pathology 70(3): 667-675 McTaggart AR, du Plessis E, Roux J, Barnes I, Fraser S, Granados GM, Ho WH, Shuey LS, Drenth A. 2020. Sexual reproduction in populations of *Austropuccinia psidii*. *Eur J Plant Pathol*. 156: 537-545

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

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Beyond Myrtle Rust: next generation tools to 'engineer' forest ecosystem resilience to plant pathogens Research Area 1.2: Ecosystem Impacts	This programme aims to accelerate understanding of pathogen dynamics, improve predictions of complex pathogen impacts on ecosystem function, develop novel, socially acceptable mitigation technologies and enhance kaitiakitanga within MR affected landscapes. • Broad scale investigation of *A psidii* impacts on ecosystem functions, including nutrient and carbon cycling • Impacts of pathogen spread on the forest microbiome both above and below ground will be explored. • The influence of plant traits over disease susceptibility, infection mode, and rate of spread will be examined.	Ministry for Business, Innovation and Employment (MBIE)	Manaaki Whenua	Current	Theme B - Epidemiology, ecosystems and resilience	Risk Assessment/ Ecosystem Impacts Host, Pathogen and Environment	N/A	To be completed in 2024. For additional updates and information go to the Beyond Myrtle Rust website. Jo I, Bellingham PJ, McCarthy JK, Easdale TA, Padamsee M, Wiser SK *et al.* 2022. Ecological importance of the Myrtaceae in New Zealand's natural forests. *Journal of Vegetation Science* **33**:e13106 McCarthy JK, Wiser SK, Bellingham PJ, Beresford RM, Campbell RE, Turner R, Richardson SJ 2021. Using spatial models to identify refugia and guide restoration in response to an invasive plant pathogen. *Journal of Applied Ecology* **58**(1): 192-201. Beresford R Campbell R. 2021. Myrtle rust weather-risk update and commentary to 30 April 2021. 8 p. Beresford RM, Shuey LS, Pegg GS 2020. Symptom development and latent period of *Austropuccinia psidii* (myrtle rust) in relation to host species, temperature and ontogenic resistance. *Plant Pathology* **69**(3): 484-494 Beresford RM, Sutherland R. 2020. Weather associated with myrtle rust on the North Island east coast. 6 p. Schmid LMH Large MF, Galbraith M, de Lange, PJ. 2021. Observation of western honeybee (*Apis melifera*) foraging urediniospores from myrtle-rust infected maire tawake (*Syzygium maire*), Ōwairaka/Mt Albert, Tāmaki Makaurau/Auckland, New Zealand. Perspectives in Biosecurity 6: 1-7. Blanchon DJ, Ranatunga D, Marshall AJ, de Lange PJ. 2020. Ecological communities of tree species threatened by myrtle rust (*Austropuccinia psidii* (G. Winter) Beenken): The lichenised mycobiota of pōhutukawa (*Metrosideros excelsa* Sol. ex Gaertn., Myrtaceae). *Perspectives in Biosecurity* (5): 23-44. Prasad M, Schmid L, Marshall A, Blanchon D, Renner M, Baba Y, Padamsee M, de Lange P. 2022. Ecological communities of Aotearoa / New Zealand species threatened by myrtle rust (*Austropuccinia psidii* (G. Winter) Beenken): The flora and mycobiota of the endemic genus *Lophomyrtus* Burret. Perspectives in Biosecurity **7**: 34–70. Heenan PB, McGlone MS, Mitchell CM, McCarthy JK, Houliston GJ. 2023. Genotypic variation, phylogeography, unified species concept, and the 'grey zone' of taxonomic uncertainty in kānuka: recognition of *Kunzea ericoides* (A.Rich.) Joy Thomps. sens. lat. (Myrtaceae). New Zealand Journal of Botany: 1-30. NOTE: funded by Strategic Science Investment Funding (SSIF) for Crown Research Institutes Ford M, Padamsee M, Schwendenmann L, Dopheide A, de Lange P. 2023. The mycorrhizal communities of *Lophomyrtus bullata* Burret (Myrtaceae) within three natural forest associations of New Zealand. *New Zealand Journal of Ecology* 47(1).

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Ford M. 2021. The Mycorrhizal Communities of *Lophomyrtus bullata* Burret (Myrtaceae) Within Three Natural Forest Associations of New Zealand. Unpublished Masters thesis, University of Auckland. Burdon RD, Bartlett MJ. 2022. Putative biotic drivers of plant phenology: With special reference to pathogens and deciduousness. Ecology and Evolution 12(6): e8932.
Host Pathogen and Environment	This theme evaluates the role of key environmental factors and host responses play on disease expression and severity, as well as investigating the pathogen genomes and how the pathogens *Austropuccinia psidii* and *Phytophthora agathidicida* infect their hosts. Knowledge gained will contribute to improving surveillance, control, management and conservation efforts, and it is hoped, new ways to mediate these diseases. RA 1: Te Whakahononga RA 2: He Koanga/Tipu o Te Kauri RA 3: *Phytophthora agathidicida* epidemiology RA 4: *Austropuccinia psidii* epidemiology RA 5: Deciphering the blueprint of a kauri killer RA 6: Targeting *Austropuccinia psidii* effectors	BioHeritage National Science Challenge – Ngā Rākau Taketake	Plant and Food Research	Current	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	N/A	To be completed in 2024. Updates to be provided via the BioHeritage Challenge website and Theme 6: Host Pathogen and Environment. Smith GR, Ganley BJ, Chagné D, Nadarajan J, Pathirana RN, Ryan J, Arnst EA, Sutherland R, Soewarto J, Houliston G, Marsh A, Koot E, Carnegie AJ, Menzies T, Lee DJ, Shuey LS, Pegg GS. 2020. Resistance of New Zealand Provenance *Leptospermum scoparium*, *Kunzea robusta*, *Kunzea linearis*, and *Metrosideros excelsa* to *Austropuccinia psidii*. Plant Disease 104(6): 1771-1780 Tobias PA, Schwessinger B, Deng CH, Wu C, Dong C, Sperschneider J, Jones A, Lou Z, Zhang P, Sandhu K and others 2020. *Austropuccinia psidii*, causing myrtle rust, has a gigabase-sized genome shaped by transposable elements. *G3 Genes|Genomes|Genetics* 11(3): 16. Soewarto J, Somchit C, du Plessis E, Barnes I, Granados GM, Wingfield MJ, Shuey L, Bartlett M, Fraser S, Scott P and others 2021. Susceptibility of native New Zealand Myrtaceae to the South African strain of *Austropuccinia psidii*: A biosecurity threat. Plant Pathology 70(3): 667-675 Beresford R, Soewarto J, Somchit C, Hasna L, Ramos Romero L. 2021. Vulnerability of New Zealand Myrtaceae species to natural infection by *Austropuccinia psidii* (myrtle rust). A Plant & Food Research report prepared for: Biological Heritage National Science Challenge Ngā Rakāu Taketake. Milestone No.92596 -8. Contract No.38046 var2. Job code: P/345175/02. PFR SPTS No. 21702.
Identification of asymptomatic periods	This project characterises the asymptomatic period and other phases of the *Austropuccinia psidii* infection cycle in relation to key New Zealand (NZ) host species, their seasonal host growth and temperature. The data collected will be combined and modelled in order to accurately define the seasonal risk of Myrtle Rust development on native species in NZ.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2019	Beresford RM, Shuey L, Pegg GS, Hasna L, Wright PJ, Kabir MS, Scheper RWA, King I, Walter M, Woolley. 2019. MPI 18608 Project Report Topic 1.2 — Identification of asymptomatic periods. *Biosecurity New Zealand Technical Paper* No: 2019/34 Beresford RM, Shuey LS, Pegg GS 2020. Symptom development and latent period of *Austropuccinia psidii* (myrtle rust) in relation to host species, temperature and ontogenic resistance. *Plant Pathology* 69(3): 484-494

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Identification of native and important exotic host species susceptibility to Myrtle Rust, including variability within species	An understanding of the level of susceptibility of New Zealand *Myrtaceae* species and cultivars to the pathogen *Austropuccinia psidii* is essential, so that response or management options to address the ecological consequences of Myrtle Rust in New Zealand at local and landscape levels can be developed	Ministry for Primary Industries	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2019	Smith G, Chagné D, Ganley B, Pathirana R, Ryan J, Arnst E, Sutherland R, Soewarto J, Houliston G, March A, Koot E, Carnegie A, Shuey L, Pegg G. 2019. Topic 1.1 — Identification of native and important exotic host species susceptibility to Myrtle Rust, including variability within species. *Biosecurity New Zealand Technical Paper* No: 2019/33 Smith GR, Ganley BJ, Chagné D, Nadarajan J, Pathirana RN, Ryan J, Arnst EA, Sutherland R, Soewarto J, Houliston G, Marsh A, Koot E, Carnegie AJ, Menzies T, Lee DJ, Shuey LS, Pegg GS. 2020. Resistance of New Zealand Provenance *Leptospermum scoparium*, *Kunzea robusta*, *Kunzea linearis*, and *Metrosideros excelsa* to *Austropuccinia psidii*. *Plant Disease* 104(6): 1771-1780
Implications for selected indigenous fauna of Tiritiri Matangi of the establishment of *Austropuccinia psidii* (G. Winter) Beenken (myrtle rust) in northern New Zealand	The aim of this review is to consider the potential longer-term impact of myrtle rust, with a focus on the flow-on effect to indigenous New Zealand fauna, particularly the nectarivorous species that use myrtaceous flowers as a food source.	Unitec Institute of Technology	Unitec Institute of Technology	Complete	Theme B - Epidemiology, ecosystems and resilience	Risk Assessment/ Ecosystem Impacts	2017	Galbraith M and Large M. 2017. Implications for selected indigenous fauna of Tiritiri Matangi of the establishment of *Austropuccinia psidii* (G. Winter) Beenken (myrtle rust) in northern New Zealand, *Perspectives in Biosecurity*, 2: 6–26.
Myrtle Rust Biology	This focus reflects an urgent need for tools to enable agencies and communities to collaborate to determine the presence or absence of kauri dieback and myrtle rust, and to establish ecological baselines for monitoring the long-term ecosystem effects of these two plant pathogens in a 'proof of freedom' framework. Determining presence or absence of infection is an essential building block to inform management for plant pathogens strategies and for protection of uninfected forests. Data will continue to be collected through the "Myrtle Rust Season" which runs from spring (November) to autumn (May). Priority work includes: • Monitoring impact of myrtle rust in native forest on native species, especially highly vulnerable *Lophomyrtus* spp.; • Measuring leaf flush in native Myrtaceae; • Field host susceptibility/resistance testing; • Investigating the reproduction rate of infected and non-infected trees.	BioHeritage National Science Challenge – Ngā Rākau Taketake	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Control, Protect, Cure Host, Pathogen and Environment Integrated Surveillance Risk Assessment/ Ecosystem Impacts	2021	Soewarto J, Somchit C, du Plessis E, Barnes I, Granados GM, Wingfield MJ, Shuey L, Bartlett M, Fraser S, Scott P and others 2021. Susceptibility of native New Zealand Myrtaceae to the South African strain of *Austropuccinia psidii*: A biosecurity threat. Plant Pathology 70(3): 667-675 Beresford R, Soewarto J, Somchit C, Hasna L, Ramos Romero L. 2021. Vulnerability of New Zealand Myrtaceae species to natural infection by *Austropuccinia psidii* (myrtle rust). A Plant & Food Research report prepared for: Biological Heritage National Science Challenge Ngā Rakāu Taketake. Milestone No.92596 -8. Contract No.38046 var2. Job code: P/345175/02. PFR SPTS No. 21702.

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Myrtle Rust: a significant threat to Australasia and the Pacific. Catalyst Project C11x1607	In consultation with a range of end-users, but especially the Ministry of Primary Industries and the Department of Conservation, this research will undertake research on key New Zealand plant species to: - establish their susceptibility to myrtle rust; - improve knowledge for effective seed (germplasm) storage systems; and - develop rapid in situ plant pathogen detection/surveillance systems (pandemic and Uruguay strains). Project involved seed collection and screening myrtle rust host species for resistance (screening done in South Africa).	Ministry for Business, Innovation and Employment – Catalyst Fund	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Conservation and Restoration Host, Pathogen and Environment Integrated Surveillance	2020	This project established an Australasian research nexus via an enduring collaboration between Plant Health Australia (PHA) and NZ's Better Border Biosecurity (B3) to co-ordinate immediate and future research to deliver outcomes to communities affected by diseases of Myrtaceae. The project collaborators (PFR, Scion, NSWDPI, QDAF) worked with NZ and Australia government agencies (e.g., MPI, DWAR, industry biosecurity entities (e.g., GIA), iwi, and aboriginal communities (e.g., Te Tira Whakamātaki) to address the increasing threats from myrtle rust, *Ceratocystis* and *Xylella*. Smith GR, Ganley BJ, Chagné D, Nadarajan J, Pathirana RN, Ryan J, Arnst EA, Sutherland R, Soewarto J, Houliston G and others 2020. Resistance of New Zealand Provenance *Leptospermum scoparium, Kunzea robusta, Kunzea linearis*, and *Metrosideros excelsa* to *Austropuccinia psidii*. *Plant Disease* **104**(6): 1771-1780. Soewarto J, Somchit C, du Plessis E, Barnes I, Granados GM, Wingfield MJ, Shuey L, Bartlett M, Fraser S, Scott P and others 2021. Susceptibility of native New Zealand Myrtaceae to the South African strain of *Austropuccinia psidii*: A biosecurity threat. *Plant Pathology* **70**(3): 667-675
Potential climate change impacts on myrtle rust risk in Aotearoa New Zealand	This report uses the Myrtle Rust Process Model, based on *Austropuccinia psidii* responses to climatic variables, to explore several climate change scenarios. These scenarios considered increases in temperature in conjunction with decreases in relative humidity.	Ministry for the Environment	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Risk Assessment and Ecosystem Impact	2020	Campbell R, Beresford R, Fitzherbert S, Carey-Smith T, Turner R. November 2020. Potential climate change impacts on myrtle rust risk in Aotearoa New Zealand. A Plant & Food Research report prepared for: Ministry for the Environment. Milestone No. 88789. Contract No. 38828. Job code: P/341114/01. PFR SPTS No. 20255.
Predicting Myrtle Rust distribution in New Zealand through climate matching (Phase 1)	Using the CLIMEX modelling package and based on an MPI report authored by Kriticos & Leriche (2008), a finer scale map was created predicting climate suitability for myrtle rust in New Zealand upon the first detection of the disease on the mainland.	Ministry for Primary Industries	AgResearch	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2017	J Kean unpublished. 2017. High resolution climate suitability maps for myrtle rust in New Zealand using the CLIMEX model documented by Kriticos & Leriche (2008). This was used by the Ministry of Primary Industries during the initial incursion response.
Predicting Myrtle Rust distribution in New Zealand through climate matching (Phase 2)	Three different modelling approaches (CLIMEX, MaxEnt and Multi-Model Framework) were used to project the habitat suitability for myrtle rust at both global and local scales. The model outputs were combined into a consensus model to identify localities projected to be suitable for myrtle rust according to two or three models (hotspots), and model outputs were validated by recent New Zealand reports of myrtle rust.	Bio-Protection Research Centre Better Border Biosecurity	Lincoln University (Bio-Protection Research Centre)	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2019	Narouei-Khadan HA, Worner SP, Viljanen ALH, van Bruggen AHC, Jones EE. 2020. Projecting the suitability of global and local habitats for myrtle rust (*Austropuccinia psidii*) using model consensus. *Plant Pathology* 69, 17-27 The results confirmed the optimum temperature range of this pathogen in the literature (15–25°C). Additional analysis of the precipitation variables indicated that excessive rain (more than 2000 mm in warmest quarter of the year) combined with high temperatures (>30°C) constrain pathogen establishment. Narouei-Khandan, HA, 2014. Ensemble models to assess the risk of exotic plant pathogens in a changing climate. PhD Thesis, Lincoln University.

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Risk Assessment & Ecosystem Impacts	In this theme, standardised impact measures are being developed to quantify the impact both kauri dieback and myrtle rust are having on affected ecosystems. We take a holistic view of ecosystems, meaning the impact measures will also examine broader ecological impacts, including on associated flora and fauna, on ecosystem functions and on human cultural, social and economic relationships. We also take a holistic view of the threat, meaning we will consider the effects of both the pathogens themselves and the tools and systems used to manage them. Research Area 1 – Te Whakahononga Research Area 2 – Risk assessment based on comprehensive ecological, cultural, social and economic values Research Area 3 – Ecosystem characterisation Research Area 4 – Social, cultural and economic characterisation	BioHeritage National Science Challenge – Ngā Rākau Taketake	Scion	Current	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment Risk Assessment/ Ecosystem Impacts	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Theme 3: Risk Assessment & Ecosystem Impacts Easdale T, McCarthy J, Bellingham P, Jo I, Richardson S, Wiser S. 2021. Carbon stocks and fluxes in New Zealand Myrtaceae. 39 p. **NOTE:** This report is held by Manaaki Whenua Landcare Research and pending publication of a peer reviewed paper – please contact the authors regarding availability. Zhulanov M, Soewarto J, Bartlett M, Sen D, Sutherland R, Gillard K, Miller E, Fraser S. 2022. Monitoring myrtle rust disease effects on *Lophomyrtus* spp. reproductive capability in the natural environment Aotearoa New Zealand. 27 p. **NOTE:** This report is held by Scion and pending publication of a peer reviewed paper – please contact the authors regarding availability.
Sentinel plants	Assessing the impact of myrtle rust on NZ natives in Australia and Hawaii (sentinel plants)	Better Border Biosecurity	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2013	Scott P, Miller E. 2013. Expatriate survey of native NZ *Myrtaceae* planted throughout Australia to determine their susceptibility to *Puccinia psidii* and improve management. New Zealand Forest Research Institute (Scion). 17 pp. **NOTE:** This report, associated with B3, is held by Scion – please contact them regarding availability. Scion Report No. 51832 (Internal Report 14388160). Dick MA, Williams N. 2013. *Puccinia psidii*: selection of a disease for validation of the expatriate plants concept. New Zealand Forest Research Institute (Scion). **NOTE:** This report, associated with B3, is held by Scion – please contact them regarding availability. Scion Report No. 19295
Strain Identification	Myrtle Rust strain characterisation	Ministry for Primary Industries	University of Pretoria	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2017	du Plessis E., Granados GM, Barnes I, Ho WH. Alexander BJR, Roux J, McTaggart AR. 2019. The pandemic strain of *Austropuccinia psidii* causes myrtle rust in New Zealand and Singapore. *Australasian Plant Pathology* 48:253–256

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
The Current and Future Potential Distribution of Guava Rust, *Puccinia psidii* in New Zealand	The objective of this study was to assess the potential for *Puccinia psidii* (guava rust, eucalypt rust) to establish and persist in New Zealand under current and future climate scenarios.	Ministry for Primary Industries / Ministry for Business, Innovation and Employment - FRST	Commonwealth Scientific and Industrial Research Organisation	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2008	The major results of the study were: 1. Under current climate conditions, *Puccina psidii* appears to be capable of establishing and persisting in all of the mid-to low-altitude areas of the North Island, and a substantial part of the more agriculturally productive areas of the South Island of New Zealand. The degree of climate suitability on the North Island appears very high. 2. Climate change will exacerbate these risks, substantially increasing the climatic suitability of New Zealand for *P. psidii*. 3. The rapid rate at which *P. psidii* invaded the State of Hawai'i suggests that it could spread rapidly throughout the Pacific islands, eventually reaching New Zealand. Kriticos DJ, Morin L, Leriche A, Anderson RC, Caley P (2013) Combining a Climatic Niche Model of an Invasive Fungus with Its Host Species Distributions to Identify Risks to Natural Assets: Puccinia psidii Sensu Lato in Australia. *PLoS ONE* 8(5): e64479. Kriticos DJ, Leriche A. 2008. The Current and Future Potential Distribution of Guava Rust, *Puccinia psidii* in New Zealand. *MAF Biosecurity Technical Paper* No: 2009/28.
Transmission risk via bees/beehives	To assess the movement of myrtle rust spores into, within and out from beehives, and to determine whether the spores remain viable through this process	Ministry for Primary Industries	Plant and Food Research	Complete	Theme B - Epidemiology, ecosystems and resilience	Host, Pathogen and Environment	2018	Pattemore D, Bateson M, Buxton M, Pegg G, Hauxwell C. 2018. Assessment of the risks of transmission of myrtle rust (*Austropuccinia psidii*) spores by honey bees (*Apis mellifera*). A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 74580. Contract No. 18638. Job code: P/414069/01. SPTS No. 16355
Beyond Myrtle Rust: next generation tools to 'engineer' forest ecosystem resilience to plant pathogens Research Area 1.4: Kaitiakitanga & Māori-Led Solutions	This programme aims to accelerate understanding of pathogen dynamics, improve predictions of complex pathogen impacts on ecosystem function, develop novel, socially acceptable mitigation technologies and enhance kaitiakitanga within myrtle rust affected landscapes. • A focus on strategies to facilitate Māori leadership in responses to *A psidii* • Develop a framework to assess impacts on Te Ao Māori and to prioritise management actions. • Develop protocols that support Māori-led methods to boost ecosystem resilience	Ministry for Business, Innovation and Employment	Manaaki Whenua	Current	Theme C - Te Ao Māori and Mātauranga Māori	Oranga Host, Pathogen and Environment Control, Protect, Cure	N/A	To be completed in 2024. For additional information please go to the Beyond Myrtle Rust website. Hall A. 2023. Rongoā approaches to myrtle rust control. Unpublished Masters thesis, University of Auckland. 156 p. Diprose G, Kannemeyer R, Edwards P, Greenaway A. 2023. Participatory biosecurity practices: Myrtle rust an unwanted pathogen in Aotearoa New Zealand. *New Zealand Geographer* Jerram S, Diprose G, Waipara N, Harvey M, Mullen M, Craig-Smith A, McBride C. 2023. Disease Narratives and Artistic Alternatives. *Knowledge Cultures* 11(1): 135-153.

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Cultural Licence to Operate Pre-Border Biological Control Tools in Aotearoa.	Success in this project would be the development and implementation of Māori biosecurity response plans which include mātauranga Māori in MPI's biosecurity procedures; and an understanding of the cultural impacts of the biosecurity tools being proposed or used in the response to Myrtle Rust. This project will contribute to achieving meaningful Māori engagement in the biosecurity space, specifically pre-and-post border risk assessment and tool development.	Better Border Biosecurity	Plant and Food Research	Current	Theme C - Te Ao Māori and Mātauranga Māori	Oranga Integrated Surveillance	2019	Marsh, A., H. Ropata, N. Waipara, W. Wood, and G. Garner. 2019. Mātauranga Māori - Myrtle Rust Response: A Case Study. A Plant & Food Research report prepared for: Better Border Biosecurity. SPTS No. 18316. **NOTE:** This report, associated with B3, is held by the New Zealand Institute for Plant and Food Research – please contact them regarding availability.
Engagement hui	The purpose of the hui was to improve knowledge and understanding by iwi/Māori of the potential biosecurity risks posed by new and invasive species like fruit fly and myrtle rust. Te Manukanuka o Hoturua Marae (Auckland Airport Marae). 7 August 2015.	Better Border Biosecurity	Plant and Food Research	Complete	Theme C - Te Ao Māori and Mātauranga Māori	Oranga	2015	The purpose of the hui was to improve knowledge and understanding by iwi/Māori of the potential biosecurity risks posed by new and invasive species like Fruit fly and Myrtle rust. Topical at the time were pests like Queensland fruit fly and the tomato potato psyllid, with the looming threat of diseases like Myrtle rust among others. One of the key messages was the need to improve engagement with indigenous communities in New Zealand and across Australia and the Pacific. One guest speaker, Ruth Wallace from Charles Darwin University in Darwin, spoke about the engagement model developed in partnership with PFR and how that will improve how government, especially in Australia, engages with the indigenous communities across Australia.
Engagement hui - PFR Māori summer students' hui	The Summer Student hui was an internally (PFR) funded event exposing our 2015 intake of Māori summer students to representatives from Māori organisation like Federation of Māori Affairs, Te Ohu Kaimoana and Te Tumu Paeroa. Also in attendance were representatives from Core Government organisations like MBIE, MPI TPK, and MfE. (Wellington, 24 March 2015).	Plant and Food Research	Plant and Food Research	Complete	Theme C - Te Ao Māori and Mātauranga Māori	Oranga	2015	The success of the event can be attributed to the response by attendees to the work undertaken by the students and the interest expressed in the SS programme. It was also good exposure for the students to the "Wellington community".
Māori / Pacifica students with focus on myrtle rust (summer students)	This part of the wider programme (RISK) assessing the impact of myrtle rust on NZ natives in Australia and Hawaii (sentinel plants).	Plant and Food Research	Plant and Food Research	Complete	Theme C - Te Ao Māori and Mātauranga Māori	Oranga	2015	Teulon DAJ, Alipia TT, Ropata HT, Green JM, Viljanen-Rollinson SLH, Cromey MG, Arthur K, MacDiarmid RM, Waipara MW, Marsh AT. 2015. The threat of myrtle rust to Māori taonga plant species in New Zealand. *New Zealand Plant Protection* 68: 66–75.
Māori solutions to biosecurity threats and incursions to taonga species	Key elements include investigating impacts of MR on NZ native plants in South Africa and building knowledge around preparedness and surveillance particularly among Māori communities. It is Māori-led and therefore has a strong mātauranga Māori focus.	BioHeritage National Science Challenge	Plant and Food Research	Complete	Theme C - Te Ao Māori and Mātauranga Māori	Oranga	2019	Black A, Mark-Shadbolt M, Garner G, Green J, Malcom T, Marsh A, Ropata H, Waipara NW, Wood W. 2018. How an Indigenous community responded to the incursion and spread of myrtle rust (*Austropuccinia psidii*) that threatens culturally significant plant species - a case study from New Zealand. *Pacific Conservation Biology* **25**, 348-354 Lambert S., Waipara N., Black A., Mark-Shadbolt M., Wood W. 2018. Indigenous Biosecurity: Māori Responses to Kauri Dieback and Myrtle Rust in Aotearoa New Zealand. In: Urquhart J., Marzano M., Potter C. (eds) The Human Dimensions of Forest and Tree Health. Palgrave Macmillan, Cham pp 109-137

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Te Ao Māori	Myrtle rust (*Austropuccinia psidii*) research to address critical knowledge gaps in cultural, social and scientific knowledge relating to the management of myrtle rust in New Zealand (MPI Project 18607). A Te Ao Māori research theme was prioritised to engage Māori within the research, and then to provide an understanding of the cultural impacts and mātauranga (knowledge) that could help inform the current and future management of myrtle rust in New Zealand.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme C - Te Ao Māori and Mātauranga Māori	Oranga	2019	Marsh A, Wood W, Ropata H, Waipara N, McGreal B, Mark-Shadbolt M, Malcolm T, van Schravendijk-Goodman C, Campbell R, Bullians M. 2019. Myrtle rust — Te Ao Māori Theme 2. *Biosecurity New Zealand Technical Paper* No: 2019/41
Te mauri o te rakau, te mauri o te ngahere, te mauri o te tangata	Research Area 3: Hapū solutions for Myrtle Rust Previous research (BioHeritage National Science Challenge Tranche 1: Project 2.4) recommended the need for Māori to lead their own research and the identify solutions that cater to their needs rather than those of western ideologies. This project is engaging with the Māori community, and exploring how they want to respond to the myrtle rust incursion through the designing of the workplan.	BioHeritage National Science Challenge - Ngā Rākau Taketake	Te Tira Whakamātaki	Current	Theme C - Te Ao Māori and Mātauranga Māori	Oranga Conservation and Restoration Control, Protect, Cure	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage website and Theme 1: Oranga Shadbolt MR. 2023. Whare Taonga: Seed Solutions in a Changing World. Te Mana Motuhake o te Kākano: A Māori Seed Conservation Hui. 18/10/2023 Wyse SV. 2023. Seed Banking our Indigenous Species: What do we Know? Te Mana Motuhake o te Kākano: A Māori Seed Conservation Hui. 18/10/2023 Mead A. 2023. Māori Rights and Interests in the Conservation Space. Te Mana Motuhake o te Kākano: A Māori Seed Conservation Hui. 18/10/2023 Mark Shadbolt M. 2023. So Where to From Here? TTW's Vision for our Kete. Te Mana Motuhake o te Kākano: A Māori Seed Conservation Hui. 18/10/2023
Building engagement and social licence through better understanding of public acceptance of potential long-term management options.	A review of existing knowledge through an update of international literature and recent experience on incursion response. Development of engagement tools (rubrics) and how to identify relevant motivated networks. Interviews with impacted groups and networks. Links with Te Ao Māori work led by PFR.	Ministry for Primary Industries	Scion	Complete	Theme D - Sociological complexity and socioeconomic consequences	Oranga Mobilising for Action	2019	Allen W, Grant A, Stronge D, Wegner S. 2019 Building engagement and social licence: Unpacking Social Licence to Operate and partnerships – developing rubrics for guidance and assessment. *Biosecurity New Zealand Technical Paper* No: 2019/17 Grant A, Stronge D, Allen W, Wegner S. 2019. Building engagement and social licence: Research overview and recommendations. *Biosecurity New Zealand Technical Paper* No: 2019/18 Grant A, Wegner S, Allen W. 2019. Building engagement and social licence: Understanding motivated networks. *Biosecurity New Zealand Technical Paper* No: 2019/16 Bayne K, Grant A, Soliman T, Wegner S, Allen W. 2019. Building engagement and social licence: Survey of individuals impacted by myrtle rust. *Biosecurity New Zealand Technical Paper* No: 2019/14 (Topic 1.0-3) Stronge D, Allen W, Wegner S, Grant A. 2019. 2017 myrtle rust biosecurity response: A Taranaki case study. *Biosecurity New Zealand Technical Paper* No: 2019/15 (Topic 1.0-4)

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Develop monitoring approaches (including establishing baselines) for assessing impacts of myrtle rust to environmental, economic, social and cultural values over time, and for understanding the impact of management interventions	To evaluate the consequences of myrtle rust, New Zealand requires robust indicators for environmental, economic and socio-cultural systems. This project will build a step-wise framework to identify indicators that can be implemented as data become available.	Ministry for Primary Industries	Scion	Complete	Theme D - Sociological complexity and socioeconomic consequences	Oranga Mobilising for Action Risk Assessment/ Ecosystem Impacts	2019	Velarde SJ, Grant A, Bellingham PJ, Richardson SJ, Wegner S, Soliman T. 2019. MPI 18607 Project Report. Evaluating impacts of and responses to myrtle rust in New Zealand. *Biosecurity New Zealand Technical Paper* No.: 2019/32
Economic Impact Assessment	Comprehensive assessment of the potential economic impacts of myrtle rust to all sectors on mainland NZ. Work supports and informs future decision-making and cost-benefit analyses.	Ministry for Primary Industries	NZ Institute of Economic Research	Complete	Theme D - Sociological complexity and socioeconomic consequences	Mobilising for Action Risk Assessment/ Ecosystem Impacts	2017	Ballingall J, Pambudi D. 2017. Economic impacts of Myrtle rust: A dynamic computable general equilibrium assessment. *NZIER final report to Ministry for Primary Industries*.
Mobilising for Action	The 'Mobilising for Action' research investment focuses on the human dimensions of forest health management, specifically kauri dieback and myrtle rust. It will develop and support research that explores the connections between people and the ngahere (forest) specifically, and people and te taiao more generally. Research Area 1: Mātauranga / Māori Knowledges Research Area 2: Pūtaiao / Western Science Research Area 3: Papa Noho / Interface	BioHeritage National Science Challenge - Ngā Rākau Taketake	University of Auckland	Current	Theme D - Sociological complexity and socioeconomic consequences	Mobilising for Action Oranga	N/A	To be completed in 2024. For additional updates and information please go to BioHeritage Challenge website, Theme 2: Mobilising for Action and www.mobilisingforaction.nz Greenaway, A., Hohaia, H., Le Heron, E. *et al.* 2021 Methodological sensitivities for co-producing knowledge through enduring trustful partnerships. *Sustain Sci.* 17: 433 - 447. Dell K, Komene TM, Tassell-Matamua N, Pomare P, Masters-Awatere B. 2022. Te ara o te moa: Patua te ngangara e kai ana i nga rakau taketake o Aotearoa. MAI Journal 11(1): 6. Apiti A, Tassell-Matamua N, Lindsay N, Dell K, Pomare P, Erueti B, Masters-Awatere B, Te Rangi M. 2023. Indigenous Māori of Aotearoa (New Zealand): Environmental Identity, Rather Than Māori Identity Per Se, Has Greatest Influence on Environmental Distress. Ecopsychology 15(2): 119-129. Apiti A, Tassell-Matamua N, Moriarty T. 2023. He Taonga Kē Ngā Kaumātua: Kaumātua Perspectives of te Taiao, Ngahere and Taonga Species. Knowledge Cultures 11(1): 19-33.

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Ayala M. 2023. Walking, Sensing, Knowing: An Ethnography on Foot Around Forest Biosecurity Interventions in Te-Ika-ā-Māui. Knowledge Cultures 11(1): 260-281. Ehler K-S, Addison C, Grant A, Finlay-Smits S. 2023. Neoliberal Knowledge Production in Aotearoa New Zealand: Confronting Kauri Dieback and Myrtle Rust. Knowledge Cultures 11(1): 282-306. Erueti B, Tassell-Matamua N, Pomare P, Masters-Awatere B, Dell K, Te Rangi M, Lindsay N. 2023. 'Pūrākau o te Ngahere': Indigenous Māori Interpretations, Expressions and Connection to Taonga Species and Biosecurity Issues. Knowledge Cultures 11(1): 34–54. Greenaway A, MacBride-Stewart S, Grant A, Finlay-Smits S, Ayala M, Allen W, O'Brien L, Martin M. 2023. Positioning Research to Improve Tree-Biosecurity Relations. Knowledge Cultures 11(1): 234-259. Harvey M, McEntee M. 2023. Mobilising for Action: Introduction to the Special Issue. Knowledge Cultures 11(1): 9-18. Harvey M, Mullen M, Waipara NW, Jerram S, Craig-Smith A, McBride C. 2023. Toi Taiao Whakatairanga: Tukanga: Processes of Navigating the Interface between Art Curation/Research, Forest Ecologies and Māori Perspectives. Knowledge Cultures 11(1): 115-135. Jerram S, Diprose G, Waipara N, Harvey M, Mullen M, Craig-Smith A, McBride C. 2023. Disease Narratives and Artistic Alternatives. Knowledge Cultures 11(1): 135-153. MacBride-Stewart S, O'Brien L, Grant A, Ayala M, Finlay-Smits S, Allen W, Greenaway A. 2023. Healing Fragmentation of Forest Biosecurity Networks: A Conceptual and Reflexive Mapping Analysis of Postcolonial Relations that Matter in Aotearoa|New Zealand and Cymru|Wales. Knowledge Cultures 11(1): 205-233. Matamua N, Moriarty, TR. Tassell-Matamua, N. 2023. Mai i te Pū ki te Wānanga: Interpreting Synchronistic Meaning Through a Wānanga Methodology. Knowledge Cultures 11(1): 84 - 97. McEntee M, Harvey M, Mullen M, Houghton C, Craig-Smith A. 2023. Interweaving Multiple Knowledges to Support Children's Participation and Engagement in Biosecurity and Forest Health: Toitū te Ngahere. Knowledge Cultures 11(1): 154–183. Tassell-Matamua N, Boasa-Dean T, McEntee M. 2023. Indigenous Knowledge Revitalisation: Indigenous Māori Gardening and its Wider Implications for the People of Tūhoe. Knowledge Cultures 11(1): 98-114.

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Mullen M, Jerram S, Harvey M, Waipara N, Athena C. 2023. Artistic practice, public awareness, and the ngahere: art–science–Indigenous Māori collaborations for raising awareness of threats to native forests. Ecology and Society 28(4).
Non-market valuation of biodiversity impacts	Choice modelling of the NZ public to determine the social value of biodiversity impacts from myrtle rust. Impacts of biodiversity loss and impacts to landscapes and ecosystems for New Zealanders under low, medium and high impact scenarios.	Ministry for Primary Industries	Lincoln University - Agribusiness and Economics Research unit	Complete	Theme D - Sociological complexity and socioeconomic consequences	Mobilising for Action Risk Assessment/ Ecosystem Impacts	2017	Tait P and Rutherford P. 2017. Non-market economic valuation of myrtle rust management benefits for New Zealand residents. *MPI Technical Paper* 2017/59. Also published by Lincoln University
Beyond Myrtle Rust: next generation tools to 'engineer' forest ecosystem resilience to plant pathogens Research Area 1.3: Novel Mitigation Technologies	This programme aims to accelerate understanding of pathogen dynamics, improve predictions of complex pathogen impacts on ecosystem function, develop novel, socially acceptable mitigation technologies and enhance kaitiakitanga within MR affected landscapes. • Determine the genetic basis of host resistance using mānuka (*Leptospermum scoparium*) as a case study • Select pathogen resistant genetic lines of mānuka • Search for biological control agents among Myrtaceae microbiome members, and investigate their mechanisms • Search Māori rongoā solutions with biocontrol capabilities	Ministry for Business, Innovation and Employment	Manaaki Whenua	Current	Theme E -Species conservation, disease control and management	Oranga Conservation and Restoration Host, Pathogen and Environment Control, Protect, Cure	N/A	To be completed in 2024. For additional updates and information please go to the Beyond Myrtle Rust website. Sun Y, Tayagui A, Sale S, Sarkar D, Nock V, Garrill A. 2021. Platforms for High-Throughput Screening and Forstanleyce Measurements on Fungi and Oomycetes. *Micromachines* 12: 639 Degnan RM, McTaggart AR, Shuey LS, Pame LJS, Smith GR, Gardiner DM, Nock V, Soffe R, Sale S, Garrill A, Carroll BJ, Mitter N, Sawyer A. 2023. Exogenous double-stranded RNA inhibits the infection physiology of rust fungi to reduce symptoms in planta. *Mol Plant Pathol*. 24: 191-207

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Building resilience and provenance into an authentic Māori honey industry.	This research is focused on supporting the honey industry to increase production of native honeys and improve their value, as well as more sustainably manage the honey resource. It is not directly addressing myrtle rust eradication or management, but aspects have potential to support understanding of how to manage the consequences of myrtle rust, particularly with respect to the resilience of current manuka honey industry. Manuka genetics subcontract: Plant and Food Research in collaboration with Manaaki Whenua Landcare Research and Māori partners are studying the genetic diversity of mānuka using state of the art whole genome sequencing technologies.	Ministry for Business, Innovation and Employment - Endeavour Fund	Manaaki Whenua	Current	Theme E -Species conservation, disease control and management	Oranga Conservation and Restoration Control, Protect, Cure	2021	This is a resource for understanding manuka resistance, populations management and germplasm conservation. Clearwater, M.J., Noe, S.T., Manley-Harris, M., Truman, G.-L., Gardyne, S., Murray, J., Obeng-Darko, S.A. and Richardson, S.J. (2021), Nectary photosynthesis contributes to the production of mānuka (*Leptospermum scoparium*) floral nectar. *New Phytol,* 232: 1703-1717 Thrimawithana AH, Jones D, Hilario E, Grierson E, Ngo HM, Liachko I, Sullivan S, Bilton TP, Jacobs JME, Bicknell R *et al.* 2019. A whole genome assembly of *Leptospermum scoparium* (Myrtaceae) for mānuka research. *New Zealand Journal of Crop and Horticultural Science* 47(4): 233-260 Noe S, Manley-Harris M, Clearwater MJ. 2019. Floral nectar of wild mānuka (*Leptospermum scoparium*) varies more among plants than among sites, *New Zealand Journal of Crop and Horticultural Science*, 47(4), 282-296 Clearwater MJ, Revell M, Noe S, Manley-Harris M 2018. Influence of genotype, floral stage, and water stress on floral nectar yield and composition of mānuka (*Leptospermum scoparium*). *Annals of Botany* 121(3): 501-512

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Conservation and Restoration	Conservation and restoration of kauri and native plants vulnerable to myrtle rust for future generations requires a Te Ao Māori world view and appropriate governance arrangements over the whenua – not just where adult plants grow but also where they can potentially regenerate. It requires a Te Ao Māori world view about if and where ex situ cultivation is appropriate to secure these taonga. Working from a pathogen host and ecosystem point of view, this investment incorporates conservation biology principles to make sure susceptible plant species survive myrtle rust and kauri dieback in Aotearoa. Research Area 1: Genetic markers to guide conservation and restoration of taonga under threat of kauri dieback Research Area 2: Tikanga-driven conservation of taonga species Research Area 3: Ensuring effectiveness of Māori who lead conservation activities for taonga species Research Area 4: Landscape-level restoration of taonga Research Area 5: Protocols for the effective long-term seed collection and storage of taonga to ensure that the species can survive even the worst-case scenario	BioHeritage National Science Challenge - Ngā Rākau Taketake	Manaaki Whenua Landcare Research	Current	Theme E -Species conservation, disease control and management	Conservation and Restoration	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage website and Theme 7: Conservation and Restoration. van der Walt K, Burritt DJ, Nadarajan J 2022. Impacts of Rapid Desiccation on Oxidative Status, Ultrastructure and Physiological Functions of *Syzygium maire* (Myrtaceae) Zygotic Embryos in Preparation for Cryopreservation. *Plants* **11**(8): 1056. Kuru R, Marsh A, Ganley B 2021. Elevating and Recognising Knowledge of Indigenous Peoples to Improve Forest Biosecurity. *Frontiers in Forests and Global Change* **4**(118). Smissen RD, Heenan PB, Maurin KJL 2021. New Zealand endemic *Neomyrtus* is sister to New Caledonian endemic *Myrtastrum* (Myrtaceae, Myrteae). *New Zealand Journal of Botany*: 1-14. Bettoni JC, van der Walt K, Souza JA, McLachlan A, Nadarajan J. 2023. Sexual and asexual propagation of *Syzygium maire*, a critically endangered Myrtaceae species of New Zealand. New Zealand Journal of Botany: 1-18. Heenan PB, McGlone MS, Mitchell CM, McCarthy JK, Houliston GJ. 2023. Genotypic variation, phylogeography, unified species concept, and the 'grey zone' of taxonomic uncertainty in kānuka: recognition of *Kunzea ericoides* (A.Rich.) Joy Thomps. sens. lat. (Myrtaceae). New Zealand Journal of Botany: 1-30. NOTE: funded by Strategic Science Investment Funding (SSIF) for Crown Research Institutes van der Walt K, Nadarajan J. 2023. Seed Storage Physiology of *Lophomyrtus* and *Neomyrtus*, Two Threatened Myrtaceae Genera Endemic to New Zealand. Plants 12(5): 1067. Van Der Walt K, Nadarajan J, Mathew L, Bettoni JC, Souza JA. 2023. Advances in cryopreservation of *Syzygium maire* (swamp maire, maire tawake) zygotic embryos, a critically endangered tree species endemic to New Zealand. *Frontiers in Conservation Science* 4 Wyse SV, Carlin TF, Etherington TR, Faruk A, Dickie JB, Bellingham PJ. 2023. Can seed banking assist in conserving the highly endemic New Zealand indigenous flora? *Pacific Conservation Biology*(30)

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Cryopreservation - developing in-vitro conservation protocols	Some species of myrtles cannot have seed stored in an orthodox way (e.g. swamp maire) or don't produce much viable seed (e.g. Bartlett's rata). We need to explore whether seeds or other tissues can be stored using cryopreservation methods and then be propagated. This will assist with the urgent need to establish our insurance policy against loss of biodiversity.	Ministry for Primary Industries	Plant and Food Research	Current	Theme E - Species conservation, disease control and management	Conservation and Restoration	N/A	Nadarajan J, van der Walt K, Pathirana R. 2019. Assessing cryopreservation potential for recalcitrant Myrtaceae germplasm. (Poster) van der Walt K, Nadarajan J, Burritt DJ, Kemp P. 2019. Cryopreservation Of Zygotic Embryos of New Zealand's Critically Endangered Tree, *Syzygium maire* (Swamp Maire). *Cryobiology* 91: 161. (CRYO 2019, San Diego, 23/07/2019) Abstract: and Recording Nadarajan J, van der Walt K, Pathirana R 2019. Seed banking and germ plasm research strategy. MPI 18608 Project Report *Biosecurity New Zealand Technical Paper* No: 2019/38. 28 p.
Desktop review of potential disease control tools	Desktop literature review of potential disease control tools which could be effective against Myrtle Rust. This is a literature review based on published papers, with recommendations for potential work/options.	Better Border Biosecurity	Scion	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2019	Chng S, Soewarto J, Adusei-Fosu K, Rolando C, Ganley R, Padamsee M, Waipara W, Grant A, Wegner S, Gee M. 2019. Potential disease control tools most likely to be effective against *Austropuccinia psidii. Biosecurity New Zealand Technical Paper* No.: 2019/27
Electrotaxis and protrusive force generation in fungal and oomycete pathogens – Pathways to new biocontrol strategies	The aim is to establish the antifungal properties of new compounds, plants and other species for the development of novel treatments. To do so, lab-on-a-chip devices will be developed to further understand how fungi and oomycetes find targets and physically invade them. The devices will include arrays of electrodes to determine how spores locate tree roots, and whether roots can be protected using external electric fields. They will also include force-sensing micropillars to help determine the internal mechanisms by which the fungi and oomycetes generate the mechanical forces they use to penetrate their targets. If the factors that underlie all these mechanisms can be determined, this may impact how we address the many diseases and infections that occur due to pathogenic fungi and oomycetes.	Ministry for Business, Innovation and Employment – Rutherford Discovery Fellowship	University of Canterbury	Current	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2024	Sun Y, Tayagui A, Sale S, Sarkar D, Nock V, Garrill A. 2021. Platforms for High-Throughput Screening and Forstanleyce Measurements on Fungi and Oomycetes. *Micromachines* 12: 639
Eradication data base	Data on rust is a small part of this project covering attempts and outcomes of plant pathogen eradications including rusts.	Better Border Biosecurity	Better Border Biosecurity	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2017	Smith GR, Fletcher JD, Marroni V, Kean JM, Stringer LD, Vereijssen J. 2017. Plant pathogen eradication: determinants of successful programs. *Australasian Plant Pathology* 46(3):277-284

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Fungicide trials associated with Myrtle Rust control in New Zealand	Myrtle rust is a fungal disease of members of the Myrtaceae plant family. It was detected in New South Wales in 2010 and in New Zealand in 2017. This study investigated the role of different fungicides and different timings of application relative to a single inoculation time for protectant and curative activity against myrtle rust. Of the chemical options investigated Amistar Xtra, Scorpio and Bayfidan were generally the best options for protection and control of myrtle rust infection in one variety of *Metrosideros* and one variety of *Lophomyrtus*. Future work should consider how to improve the coverage of plant canopies and stems for better chemical cotrol of myrtle rust.	Ministry for Primary Industries	NSW Department of Primary Industries	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2018	Cuddy WS, Carnegie A. 2018. Fungicide Trials Associated with Myrtle Rust Control in New Zealand. *Final Report for NZ MPI*
Initial identification of genetic markers linked to resistance	Eucalyptus trees with resistance to the *A. psidii* strains present in Brazil have been developed using breeding and molecular systems since the 1970s and are grown commercially. Genetic loci associated with resistance have been identified in *E. grandis* in Brazil and in other Eucalypt species in Australia.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme E -Species conservation, disease control and management	Conservation and Restoration	2019	Chagné D, Buck E, Koot E, Silvester N, Dungey H, Freeman J, Telfer E. 2019. Topic 1.4 — Initial identification of genetic markers linked to resistance. *Biosecurity New Zealand Technical Paper* No: 2019/36
Myrtle Rust Chemical Control Literature review	Literature review of current chemical control tools and fungicides in context of Myrtle Rust and Myrtaceae.	Ministry for Primary Industries	Scion	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2019	Adusei-Fosu K, Rolando CA. 2019. Chemical control - review of control methods and fungicides. *Biosecurity New Zealand Technical Paper* No.: 2019/24
Ngā Rākau Taketake Seed Investment	This is a small research investment that primarily focused on understanding alternative host species for kauri dieback, and some initial investigative work on leaf assays for Myrtle Rust.	BioHeritage National Science Challenge - Ngā Rākau Taketake	Lincoln University	Current	Theme E -Species conservation, disease control and management	Control, Protect, Cure Host Pathogen and Environment	2022	Dobbie K, Bartlett M, Lloyd A, Waller L. 2022. Optimising methods for screening the susceptibility of host species populations to myrtle rust. 16 p.
Nursery Industry Accreditation Scheme	To scope and develop a comprehensive plant production biosecurity scheme which informs plant producer certification across the plant production industry. This will minimise biosecurity risk and harness the critical skills and observations that exist in the industry to protect and grow New Zealand.	Ministry for Primary Industries	NZ Plant Producers Inc.	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2018	Plant Pass is a voluntary certification scheme officially launched in May 2022 for New Zealand plant producers recognising good biosecurity practice and providing assurance for plant buyers. https://www.plantpass.org.nz/ This scheme includes a Myrtle Rust Specific Module for producers growing myrtles Plant Production Management System Overview Myrtle Rust Specific Module The NZPPI Plant Disease Management Platform contains up-to-date weather summaries, seasonal growing factors and forecast information. The platform includes the Myrtle Rust climate model to help producers manage the disease using forecasted climate information.

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Optimising fungicide use in New Zealand nurseries	This work aims to optimise fungicide use in nurseries including the development of a risk-based spraying strategy (using a climate risk model) and develop guidelines to prevent fungicide resistance	Ministry of Primary Industries	Plant and Food Research	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2022	Beresford RM, Wright PJ 2022. Risk-based fungicide management for myrtle rust in nurseries. Plant & Food Research report to Ministry for Primary Industries (MPI ref. C0033063). July 2022. PFR SPTS No. 22715.
Pilot trials for control of myrtle rust using fungicides	Pilot study to trial efficacy of selected fungicides and adjuvants (Glasshouse studies). Project included development of inoculation methods. Small-scale testing of fungicidal treatments on New Zealand native trees and ecosystems to assess any off-target risks. This will help us decide if it is worth taking the risk to prophylactically treat important shrubs or trees (e.g. on DOC land) or whether different fungicides should be used for specific tree/shrub species.	Ministry for Primary Industries	Scion	Complete	Theme E -Species conservation, disease control and management	Control, Protect, Cure	2019	Adusei-Fosu K, Rolando CA. 2019. Pilot trials for control of myrtle rust using fungicides. *Biosecurity New Zealand Technical Paper* No.: 2019/25 Pathan AK, Cuddy W, Kimberly MO, Adusei-Fosu K, Rolando CA, Park RF 2020. Efficacy of Fungicides Applied for Protectant and Curative Activity Against Myrtle Rust. *Plant Disease* **104**(8): 2123-2129 Adusei-Fosu, K., Rolando, C.A., Richardson, B. *et al.* 2021. Evaluating the efficacy of potential fungicide-adjuvant combinations for control of myrtle rust in New Zealand. *J Plant Diseases and Protection* **128**: 1501 - 1515
Resistant plants and potential relationship with endophyte populations	The impact of endophytes of myrtaceous species on infection and epidemiology of *A. psidii* is unknown. Preliminary work on mānuka substantiates a functional role for endophytes in growth, chemistry and plant protection: the latter aspect will be investigated as a contributor to Myrtle Rust resistance.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme E -Species conservation, disease control and management	Host Pathogen and Environment Control, Protect, Cure	2019	Ridgeway H, Ganley B, Nieto-Jacobo F, Chng S, Soewarto J. 2019. MPI 18608 Project Report Topic 1.5 — Relationship with endophyte populations. *Biosecurity New Zealand Technical Paper* No: 2019/37
Scoping a resistance breeding programme: strategy pathways for implementation	The objective of this project was to develop a breeding framework to facilitate long-term maintenance of healthy populations of Myrtaceous species in New Zealand. Myrtle rust has the potential to cause significant impacts upon native and introduced Myrtaceae species in New Zealand, including native species extinctions and broader environmental impacts. Breeding approaches, including germplasm conservation, genetic improvement for enhanced resistance, and reforestation with genetically improved material in severely impacted taxa, have clear potential to reduce the impacts of the disease (Sniezko and Koch 2017). However, myrtle rust will have variable impact across the c. 200 native and exotic Myrtaceae species in New Zealand, and different species will be a higher priority than others for action, so it will be important to formulate appropriate breeding responses on a case-by-case basis.	Ministry for Primary Industries	Scion	Complete	Theme E -Species conservation, disease control and management	Conservation and Restoration	2019	Freeman J, Bus V, Klapste J, Jesson L, Dungey H. 2019. MPI 18607 Project Report Scoping a resistance breeding programme: Strategy pathways for implementation (3.5-3). *Biosecurity New Zealand Technical Paper* No: 2019/28

Myrtle Rust (*Austropuccinia psidii*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Seed banking and germplasm research strategy	Within 7 years, myrtle rust has caused the localised extinction of some *Myrtaceae* species in Australia. Wider scale species extinction is a distinct possibility as the pathogen continues to spread. Conversation of species and ensuring future access to genetic variation via storage of seed or germplasm (e.g. tissue culture) is a key component of long-term management response to the threat posed by this pathogen to NZ's unique *Myrtaceae* species.	Ministry for Primary Industries	Plant and Food Research	Complete	Theme E -Species conservation, disease control and management	Conservation and Restoration	2019	Nadarajan J, van der Walt K, Pathirana R. 2019. MPI 18608 Project Report Topic 3.1 - Seed banking and germ plasm research strategy. Biosecurity New Zealand Technical Paper No: 2019/38 Van der Walt K. 2020. Investigating cryopreservation options for *Syzygium maire*, a threatened endemic New Zealand tree. *Australian Plant Conservation* **29**(3) 22-25 Van der Walt K, Kemp P, Sofkova-Bobcheva S, Burritt DJ, Nadarajan J 2020. Seed development, germination, and storage behaviour of *Syzygium maire* (Myrtaceae), a threatened endemic New Zealand tree. *New Zealand Journal of Botany* **59**(2): 198-216. Nadarajan J, van der Walt K, Lehnebach CA, Saeiahagh H, Pathirana R. 2021. Integrated ex situ conservation strategies for endangered New Zealand Myrtaceae species, *New Zealand Journal of Botany* **59**(1): 72-89 van der Walt K 2022. Ex situ conservation of Myrtaceae. A response to Myrtle Rust in the Pacific Region. Unpublished Doctoral thesis, Massey University, Massey University. 240 p. van der Walt K, Alderton-Moss J, Lehnebach CA 2022. Cross-pollination and pollen storage to assist conservation of *Metrosideros bartlettii* (Myrtaceae), a critically endangered tree from Aotearoa New Zealand. *Pacific Conservation Biology*: -.
Seed collection for long-term conservation of species and populations at risk from myrtle rust impacts	The aim of the seed collection is for it to act as an insurance policy against regional or national extinctions of native Myrtaceae. Seed collections have been coordinated through a seed collection framework developed as part of the DOC germplasm strategy for native Myrtaceae, and in response to myrtle rust.	Department of Conservation	Department of Conservation	Current	Theme E -Species conservation, disease control and management	Conservation and Restoration	N/A	This project is being undertaken in partnership with the Ministry for Primary Industries and NZ Indigenous Flora Seed Bank (Massey University).